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FLOOD INSURANCE STUDY

WAVE HEIGHT ANALYSIS

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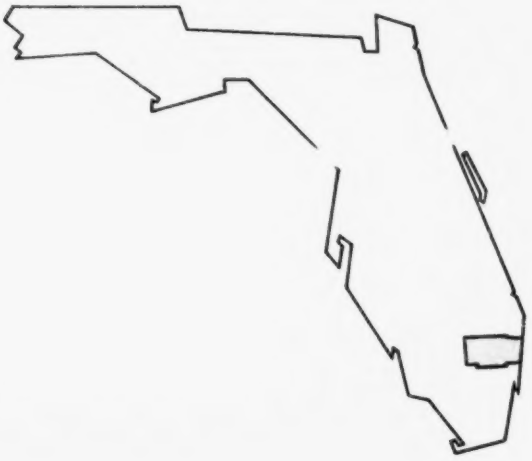

BROWARD COUNTY, FLORIDA
UNINCORPORATED AREAS

JUNE 15, 1982

Federal Emergency Management Agency

COMMUNITY NUMBER-125093

ANALYSIS OF WAVE HEIGHTS
FOR
BROWARD COUNTY, FLORIDA

FEDERAL EMERGENCY MANAGEMENT AGENCY

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1.0 INTRODUCTION

1.1 Background and Purpose

The Federal Emergency Management Agency recently adopted recommendations by the National Academy of Sciences to include prediction of wave heights in Flood Insurance Studies for coastal communities subject to storm surge flooding, and to report the estimated wave crest elevations as the base flood elevations on Flood Insurance Rate Maps (FIRMs).

Previously, FIRMs were produced showing only the stillwater storm-surge elevations due to the lack of a suitable and generally applicable methodology for estimating the wave crest elevations associated with storm surges. These stillwater elevations were subsequently stipulated in community flood plain management ordinances as the minimum elevation of the first floor of new construction. Communities and individuals had to consider the additional hazards of velocity waters and wave action on an ad hoc basis. Because there has been a pronounced tendency for buildings to be constructed only to meet minimum standards, without consideration of the additional hazard due to wave height, increasing numbers of people could unknowingly be accepting a high degree of flood-related personal and property risk in coastal areas subject to wave action. Therefore, the Federal Emergency Management Agency has pursued the development of a suitable methodology for estimating the wave crest elevations associated with storm surges. The recent development of such a methodology by the National Academy of Sciences (Reference 1) has led to the adoption of wave crest elevations for use as the base flood elevations in coastal communities.

Among the most severe storms to pass through Broward County were those of September 1926, September 1928, September 1947, and August 1964. The hurricane of September 1926 was one of the four most destructive hurricanes of the 20th century. The Hollywood-Fort Lauderdale area suffered extensive damage due to tidal flooding and wave action. The hurricane of September 1947 resulted in widespread flooding and extensive crop damage. Winds of up to 150 miles per hour were reported at Pompano Beach.

Broward County, Florida (Unincorporated Areas), is located on the open coast and is subject to flooding from tidal surges associated with hurricanes.

The purpose of this study is to revise the FIRM for Broward County to include the effects of wave action associated with flooding from the Atlantic Ocean at the open coast and the Intracoastal Waterway.

2.0 INVESTIGATIONS

2.1 Previous Studies

Stillwater elevations for hurricane surges with 10-, 50-, 100-, and 500-year return periods were determined by the National Oceanic and Atmospheric Adminis-

tration (NOAA) for the open coast of Broward County. The 100-year stillwater elevations were used as base flood elevations for the FIRM that is now in effect for Broward County (Reference 2).

The NOAA storm-surge elevations were determined using a computer simulation model of hurricane forces (References 3 and 4). Weather records were analyzed to determine the probable atmospheric pressure drop, radius of maximum winds, and forward speed and direction of storms occurring near the study area. Using these data, in conjunction with the astronomical tides and bathymetric data, stillwater elevations for various probabilities were calculated. Results of these calculations were calibrated against tide gage records and high-water marks for historical events at various locations along the coast.

Original tidal backwater elevations for the Intracoastal Waterway in Broward County were also determined by NOAA. The determination was based on the proximity to the shoreline, the elevation of the land, and the local physiography. Empirical data were also used and included high-water marks from the storms of 1964 and 1966 recovered by field personnel.

Stillwater elevations used for the wave height analyses for the open coast and the Intracoastal Waterway between SE 15 Court and SE 19 Court were revised based on the more recent analysis done by the U.S. Army Corps of Engineers for the Fort Lauderdale Flood Insurance Study (Reference 5). This analysis was based on the original NOAA elevations for Broward County but resulted in adjusted storm-surge elevations.

Stillwater elevations for the Intracoastal Waterway north of SE 15 Court were revised based on the more recent analysis done by Tetra Tech, Inc., for the Pompano Beach Flood Insurance Study (Reference 6). This determination was approached by the joint probability method (Reference 7). This method includes the description of storm populations, a numerical hydrodynamic model of the region, and the statistical combination of the astronomical tide for the region with the computed storm tide to yield recurrence intervals of total water level.

This study is authoritative for purposes of the National Flood Insurance Program. Data presented herein either supersede or are compatible with all previous flood elevation determinations.

2.2 Data Collection and Review

All available source data applicable for the wave height analysis were collected and reviewed. Because wave height calculations are based on such parameters as the size and density of vegetation, natural barriers (such as sand dunes), buildings, and other manmade structures, it was necessary to obtain detailed information on the physical and cultural features of the study area.

Officials of Broward County and its incorporated coastal communities were contacted for maps and other possible data sources to be used in the analysis. In addition, the Florida Department of Natural Resources, Bureau of Beaches and Shores; the Florida Department of Transportation; the U.S. Army Corps

of Engineers, Jacksonville District; the U.S. Fish and Wildlife Service; Arthur V. Strock and Associates, Inc.; and the National Ocean Survey were contacted, and all applicable data sources were obtained.

The principal source materials used for the wave height analysis are described below.

a. Topographic data (ground elevations, seawall elevations, and locations of physical features) were determined using U.S. Geological Survey topographic maps at a scale of 1:24,000, with a contour interval of 5 feet (Reference 8); National Ocean Survey storm evacuation maps at a scale of 1:62,500, with a contour interval of 5 feet (Reference 9); beach profiles of the immediate Atlantic coast area obtained from the Florida Department of Natural Resources (Reference 10) and the U.S. Army Corps of Engineers (Reference 11); and Arthur V. Strock and Associates, Inc., Coastal Structures Inventory maps (Reference 12).

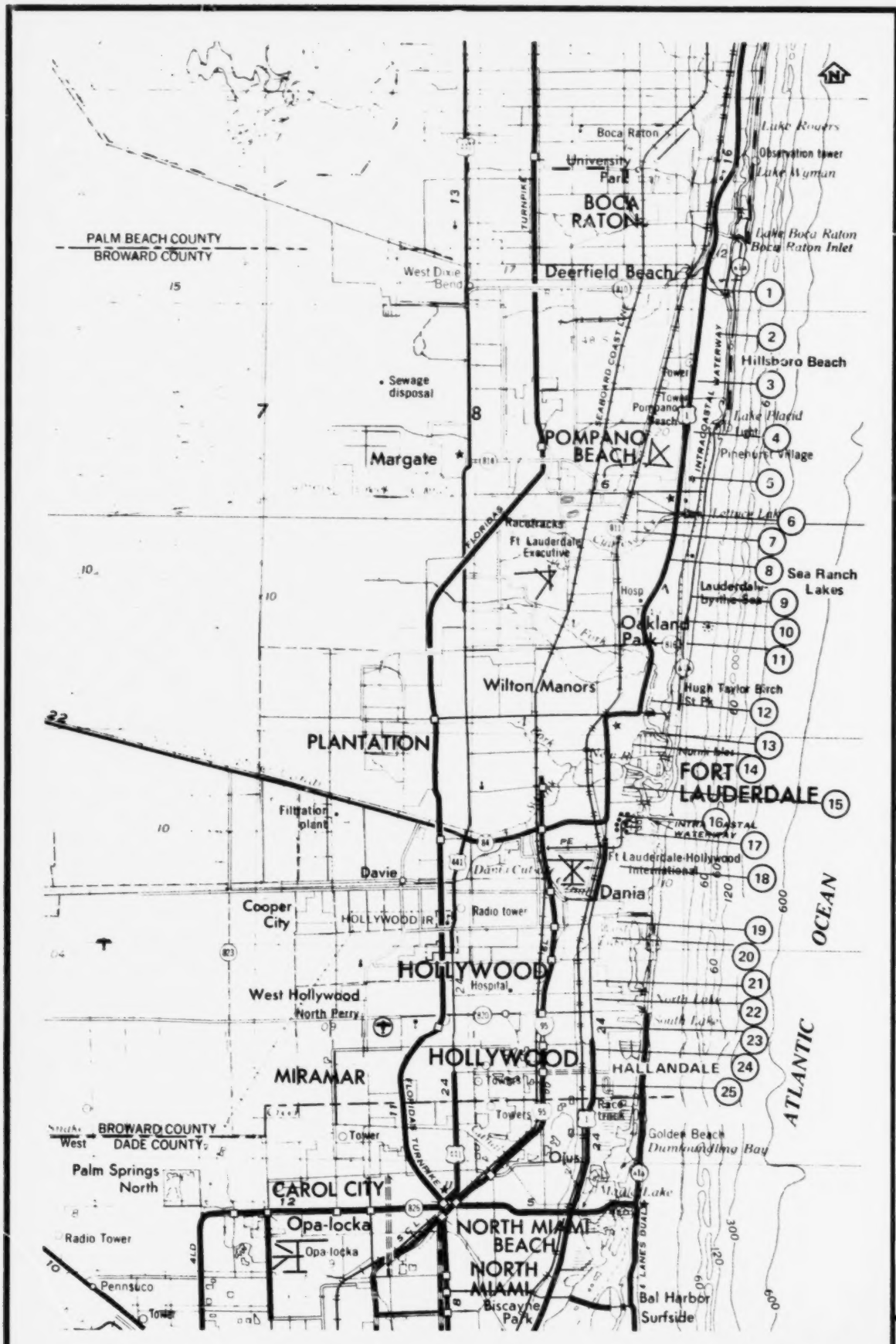
b. Recent stereoscopic aerial photography at a scale of 1:12,000 was used to determine vegetation parameters and to supplement the topographic maps for locations of physical features in Broward County (Reference 13).

2.3 Wave Height Analysis

The methodology for analyzing the effects of wave heights associated with coastal storm surge flooding is described in the National Academy of Sciences report (Reference 1). This method is based on the following major concepts. First, depth-limited waves in shallow water reach a maximum breaking height that is equal to 0.78 times the stillwater depth. The wave crest is 70 percent of the total wave height above the stillwater level. The second major concept is that wave height may be diminished by dissipation of energy due to the presence of obstructions, such as sand dunes, dikes and seawalls, buildings, and vegetation. The amount of energy dissipation is a function of the physical characteristics of the obstruction and is determined by procedures prescribed in Reference 1. The third major concept is that wave height can be regenerated in open fetch areas due to the transfer of wind energy to the water. This added energy is related to fetch length and depth.

Wave heights were computed along transects (cross section lines) in accordance with the Users Manual for Wave Height Analysis (Reference 14). The transects were located along the coastline as shown in Figure 1. They were located with consideration given to the physical and cultural characteristics of the land so that they would closely represent conditions in their locality. Transects were spaced close together in areas of complex topography and dense development. In areas having more uniform characteristics, they were spaced at larger intervals. It was also necessary to locate transects in areas where unique flooding existed and in areas where computed wave heights varied significantly between adjacent transects.

Each transect was taken perpendicular to the shoreline and extended to the inland limit of tidal flooding. Along each transect, wave heights and elevations



TRANSECT LOCATION MAP

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BROWARD COUNTY, FL

FIGURE 1

BEST DOCUMENT AVAILABLE

were computed considering the combined effects of changes in ground elevation, vegetation, and physical features. The stillwater elevations for the 100-year flood were used as the starting elevations for these computations. Wave heights were calculated to the nearest 0.1 foot, and wave elevations were determined at whole-foot increments along the transects. The location of the 3-foot breaking wave for determining the terminus of the V Zone (area with velocity wave action) was also computed at each transect. Table 1 provides a listing of the transect locations and stillwater elevations, as well as maximum wave crest elevations in the vicinity of Broward County.

Figure 2 is a profile for a typical transect illustrating the effects of energy dissipation and regeneration on a wave as it moves inland. This figure shows the wave elevations being decreased by obstructions, such as buildings, vegetation, and rising ground elevations, and being increased by open, unobstructed wind fetches. Actual wave conditions in Broward County may not necessarily include all the situations illustrated in Figure 2.

After analyzing wave heights along each transect, wave elevations were interpolated between transects. Various source data were used in the interpolation, including topographic maps (Reference 8), beach profiles (Reference 10), and aerial photographs (Reference 13), along with engineering judgment. Controlling features affecting the elevations were identified and considered in relation to their positions at a particular transect and their variation between transects.

2.4 Results

The only area affected by wave action in Broward County is along the open coast. Wave heights greater than 3 feet are diminished near the open coast by the rising ground elevation at the beach. The community is provided additional protection by a system of seawalls extending the entire length of the coast of Broward County. These seawalls are above the 100-year tidal flood plain and, therefore, were not considered to affect wave heights in the community. The maximum wave crest elevation of the Atlantic Ocean shoreline is 12 feet.

The narrowness of the Intracoastal Waterway in conjunction with the dense development of the area prevents any wave generation across the Intracoastal Waterway flood plain.

3.0 FLOOD PLAIN MANAGEMENT APPLICATIONS

A prime purpose of the National Flood Insurance Program is to encourage local governments to adopt sound flood plain management programs designed to reduce future flood losses. The FIRM for Broward County has been revised to incorporate the latest available information, including wave height data, to assist this community in developing the most appropriate and effective flood plain management measures.

Table 1.
Transect Locations, Stillwater Elevations, and Maximum Wave Crest Elevations

Transect	Location	Elevation (Feet NGVD) Stillwater	Wave Crest
7	Broward County/Pompano Beach - From the Atlantic coastline approximately 500 feet south of the intersection of South Ocean Boulevard and Sunset Lane, westward across the Intracoastal Waterway flood plain	8.0[1]	12[1]
8	Broward County/Sea Ranch Lakes/Fort Lauderdale - From the Atlantic coastline approximately 500 feet north of the intersection of South Ocean Boulevard and Gate House Road, in Sea Ranch Lakes, westward across the Intracoastal Waterway flood plain	8.0[1]	12[1]

[1]Atlantic Ocean, open coast

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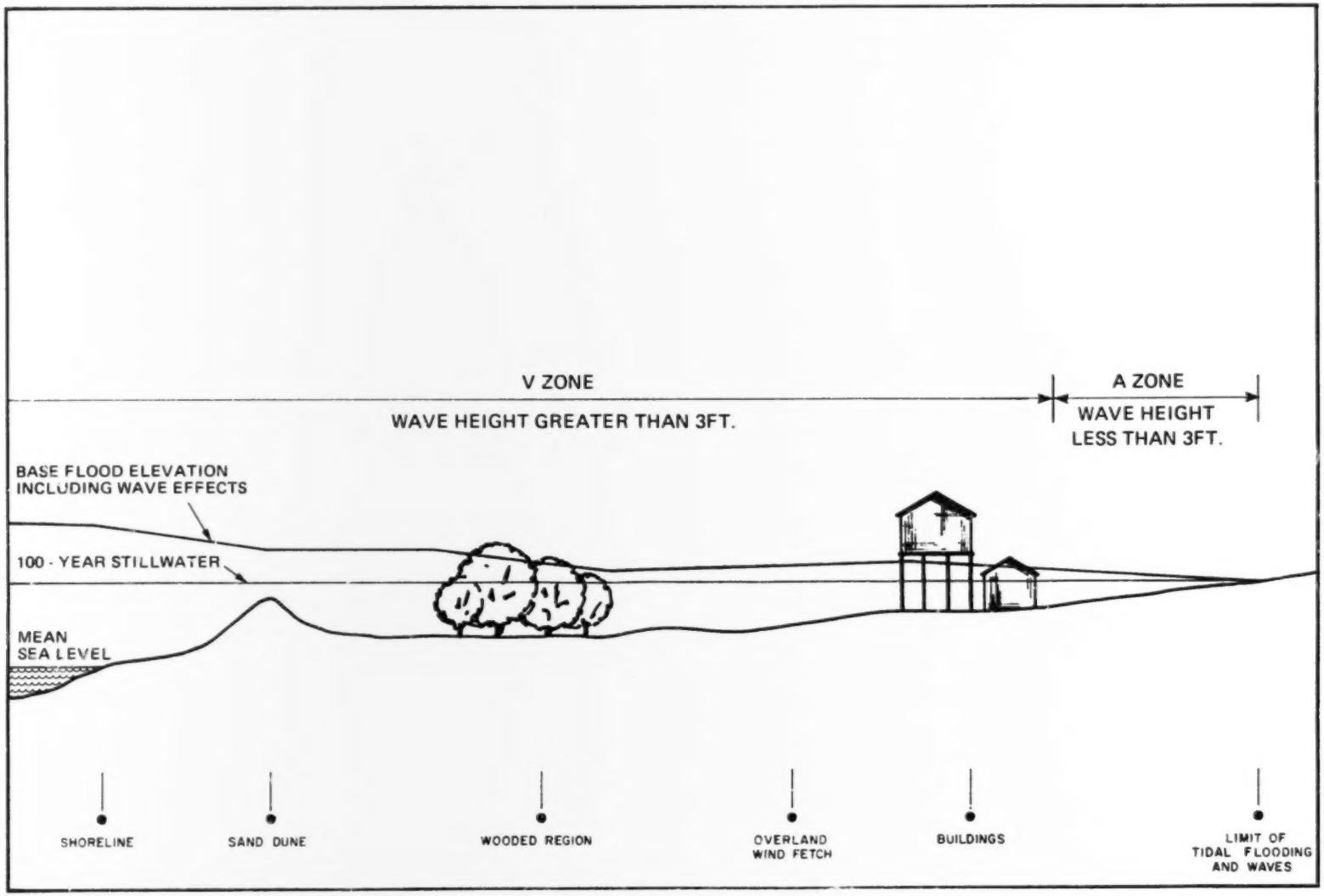

FIGURE 2
TYPICAL TRANSECT SCHEMATIC

3.1 Flood Boundaries

In order to provide a national standard without regional discrimination, the 100-year flood has been adopted by the Federal Emergency Management Agency as the base flood for purposes of flood plain management. This flood has a 1 percent chance of being equalled or exceeded each year and is expected to be exceeded once on the average during any 100-year period. The risk of having a flood of this magnitude or greater increases when periods longer than 1 year are considered. For example, over a 30-year period, there is a 26 percent chance of experiencing a flood equal to or greater than the 100-year flood. The 500-year flood plain is also shown on the FIRM to indicate areas of moderate flood hazards.

Areas inundated by the 100-year flood are shown as A and V Zones on the community's FIRM. It is in these areas that the Federal Emergency Management Agency requires local communities to exercise flood plain management measures as a condition for participation in the National Flood Insurance Program.

3.2 Base Flood Elevations

Areas within the communities studied by detailed engineering methods have base flood elevations established in A and V Zones. These are the elevations of the base (100-year) flood relative to the National Geodetic Vertical Datum of 1929. In coastal areas affected by wave action, base flood elevations are generally maximum at the open coast shoreline. These elevations generally decrease in a landward direction at a rate dependent on the presence of obstructions capable of dissipating the wave energy. Where possible, changes in base flood elevations have been shown in 1-foot increments on the FIRMs. However, where the scale did not permit, 2- or 3-foot increments were sometimes used. Base flood elevations shown in the wave action areas represent the average elevation within the zone. Current program regulations generally require that all new construction be elevated such that the first floor, including basement, is above the base flood elevation in A and V Zones.

3.3 Velocity Zones

The U.S. Army Corps of Engineers (Reference 15) has established the 3-foot breaking wave as the criterion for identifying coastal high hazard zones. This was based on a study of wave action effects on structures. This criterion has been adopted by the Federal Emergency Management Agency for the determination of V Zones. Because of the additional hazards associated with high-energy waves, the National Flood Insurance Program regulations require much more stringent flood plain management measures in these areas, such as elevating structures on piles or piers. In addition, insurance rates in V Zones are higher than those in A Zones with similar numerical designations.

The location of the V Zone is determined by the 3-foot breaking wave as discussed previously. The detailed analysis of wave heights performed in this study allowed a much more accurate location of the V Zone to be established. The V Zone generally extends inland to the point where the 100-year flood depth is insufficient to support a 3-foot breaking wave.

4.0 INSURANCE APPLICATION

The assignment of proper actuarial insurance rates requires that frequency and depth of flooding be estimated as accurately as possible. Because waves can add considerably to expected flood depths, it is important that insurance rates consider this additional hazard. The Federal Emergency Management Agency has developed a process to transform the data from this study into flood insurance criteria. This process includes the determination of Flood Hazard Factors and the designation of flood insurance zones.

4.1 Flood Hazard Factors

The Flood Hazard Factor (FHF) is the device used to correlate flood information with insurance rate tables. Correlations between property damage from floods and their FHF are used to set actuarial insurance premium rate tables.

The FHF is shown as a three-digit code that expresses the difference between the 10- and 100-year flood elevations to the nearest 0.5 foot. For example, if the difference between water-surface elevations of the 10- and 100-year floods is 0.7 foot, the FHF is 005; if the difference is 1.4 feet, the FHF is 015; if the difference is 5.0 feet, the FHF is 050. When the difference between the 10- and 100-year water-surface elevations is greater than 10.0 feet, the FHF is computed to the nearest foot.

4.2 Flood Insurance Zones

After wave elevations for the 100-year storm surge were determined and mapped, the study areas were divided into zones, each having a specific flood potential and FHF. Each zone was assigned one of the following flood insurance zone designations:

Zone V13:	Special Flood Hazard Areas inundated by the 100-year flood, and that have additional hazards due to velocity (wave action); base flood elevations shown, and zones subdivided according to FHFs.
Zones A5-A7, and A11:	Special Flood Hazard Areas inundated by the 100-year flood, with base flood elevations determined and zone designations assigned according to the FHFs.
Zone B:	Areas between the Special Flood Hazard Areas and the limits of the 500-year flood plain, including areas that are protected from the 100- and 500-year floods by dike, levee, or other water control structure; and areas subject to certain types of 100-year shallow flooding where depths are less than

	1.0 foot, or where the contributing drainage area is less than 1 square mile. Zone B is not subdivided.
Zone C:	Areas not subject to flooding by the 500-year flood. Zone C is not subdivided.

Table 2, "Flood Insurance Zone Data," summarizes the FHFs, flood insurance zones, and base flood elevations for each flooding source in the study area.

4.3 Flood Insurance Rate Map

After flood insurance zones were established for the study area, the FIRM for Broward County was revised to incorporate the new zone information. This map (Exhibit 1) contains the official delineation of flood insurance zones and base flood elevations.

In preparing the revised FIRM, updated topographic information was used to revise the open coast shoreline and some zone boundaries in areas not affected by the wave height analysis. Corporate limits and cultural features were revised using a current community map (Reference 16).

5.0 OTHER STUDIES

Flood Insurance Studies for the adjacent communities of Pompano Beach, Sea Ranch Lakes, Lauderdale-by-the-Sea, and Fort Lauderdale; and the incorporated areas of Deerfield Beach, Hillsboro Beach, Hollywood, Dania, and Hallandale are being revised concurrently with Broward County to include wave height analysis. The revised studies for these communities, with the exception of Sea Ranch Lakes, will be in agreement with this study. Differences in zone numbers between Broward County and Sea Ranch Lakes are attributed to minor variations in surge elevations used in the analyses. The Flood Insurance Study for Lighthouse Point is also in general agreement with this study.

6.0 REFERENCES

1. National Academy of Sciences, Methodology for Calculating Wave Action Effects Associated With Storm Surges, 1977

2. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Rate Map, Broward County, Florida, Scale 1:24,000, May 1978

3. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Technical Memorandum NWS TDL 52, SPLASH (Special Program to List Amplitudes of Surges from Hurricanes): Part I Landfall Storms, C.P. Jelesnianski, 1972

Table 2. Flood Insurance Zone Data

Flooding Source	Stillwater Elevation 10-Year	50-Year	100-Year	500-Year	FHF	Zone	Base Flood Elevation (Feet NGVD)*
Atlantic Ocean							
Open Coast	3.7	6.5	8.0	11.1	065	V13	10 to 12
					055	A11	8 to 10
Intracoastal Waterway							
North of SE 15 Court	4.7	6.8	7.7	8.8	030	A6	8
South of SE 15 Court to SE 19 Street	3.7	6.0	7.0	9.0	035	A7	7
South of SE 19 Street	3.6	5.4	6.0	7.5	025	A5	6

*Due to map scale limitations, base flood elevations shown on the FIRM may represent average elevations for the zones depicted.

4. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Technical Memorandum NWS TDL 52, SPLASH; Part II, General Track and Variant Storm Conditions, C.P. Jelesnianski, 1974

5. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, City of Fort Lauderdale, Florida, Revised 1978

6. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, City of Pompano Beach, Florida, 1979

7. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Technical Memorandum WBTM Hydro 11, Joint Probability Method of Tide Frequency Analysis, V.A. Myers, April 1970

8. U.S. Department of the Interior, Geological Survey, 7.5-Minute Series Topographic Maps, Scale 1:24,000, Contour Interval 5 feet: Boca Raton, Florida (1962), Photorevised (1969); Pompano Beach, Florida (1962), Photorevised (1969); Port Everglades, Florida (1962), Photorevised (1969); North Miami, Florida (1962), Photorevised (1969) and (1972); Fort Lauderdale South, Florida (1962), Photorevised (1969)

9. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Storm Evacuation Map T-15057, Scale 1:62,500, Contour Interval 5 feet: Fort Lauderdale, Florida (1977)

10. Florida Department of Natural Resources, Bureau of Beaches and Shores, Broward County Beach Profiles, Scale 1:600, June 1980

11. U.S. Army Corps of Engineers, Jacksonville District, Beach Erosion Control Projects, Broward County, Florida, Scale 1:1200, March 1980

12. Arthur V. Strock and Associates, Inc., Pompano Beach Phase II Nourishment Coastal Structures Inventory, Scale 1:1200, April 1980

13. Federal Emergency Management Agency, Stereoscopic Aerial Photographs of Broward County, Florida, Scale 1:12,000, January 1981

14. Federal Emergency Management Agency, Users Manual for Wave Height Analysis, Revised February 1981

15. U.S. Army Corps of Engineers, Galveston District, Guidelines for Identifying Coastal High Hazard Zones, June 1975

16. Broward County Cartographic Section, Broward County Metropolitan Areas, Scale 1:36,000, 1980